Geomagnetic Studies in the 19th Century British India

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Introduction

Geomagnetism, formerly called terrestrial magnetism, is the branch of science that deals with the earth's magnetic field observed on its surface, within it and extending upward to the magnetospheric boundary. Presence of earth's magnetic field was known to the Chinese about 4000 years ago. They, however, took help from earth's magnetic field for navigation about 1000 years ago, only after inventing magnetic compass[1].

The direction and strength of earth's magnetic field can be measured at its surface. It has several components, such as total intensity, horizontal intensity, vertical intensity, declination and inclination. Horizontal Intensity and Vertical Intensity are respectively horizontal and vertical components of total magnetic intensity of earth's magnetic field. Magnetic Declination is the difference between the True Meridians and the Magnetic Meridians. This difference reflects the tilt of the earth's magnetic field with respect to its axis of rotation. Since the magnetic poles and axis of rotation do not exactly coincide, compass needles do not indicate true North at most sites in the northern hemisphere, or true South at most sites in the southern hemisphere. While magnetic declination was determined in China about 1000 years ago, in Europe the concept of declination was known in early fifteenth century. The first precise measurement of declination was made by George Hartman (1489-1564), a German Astronomer in 1510 in Rome. Magnetic Inclination (dip) is the angle that the geomagnetic field is tilted with respect to the surface of the Earth. Magnetic inclination varies from 90° (perpendicular to the surface) at the magnetic poles to 0° (parallel to the surface) at the magnetic equator. Magnetic dip was first described by Robert Norman, a magnetic compass maker in London in 1581. There are three ways by which temporal variations of Earth's magnetic field occur and in turn affect exploration magnetic surveys to different extent. Secular Variations are long-term variations of Earth's magnetic field that occur slowly over a period of few years. Diurnal Variations occur over the course of a day. Magnetic Storms are magnetic activities associated with enhanced sunspot activities. During magnetic storms, earth's magnetic field becomes irregular[2].

The European Scene : From Gilbert to Gauss

Systematic work on geomagnetism began with the publication of William Gilbert's *De Magnete, Magneticisque Corporibus, et de Magno Magnete Tellure* (On the Magnet and Magnetic Bodies, and on the Great Magnet the Earth) in 1600. William Gilbert (1544-1603) was an English physician and natural philosopher. He conducted many experiments with small magnetic needles and a small spherical loadstone (his model earth) called the terrela. From experimental results, he concluded that the Earth itself was a giant loadstone.

Rene' Descartes (1596-1650), a French philosopher, mathematician and physicist gave the first illustration of a magnetic field in his book *Principia Philosophiae* (Principles of Philosophy) in 1644. He believed that the earth's magnetic field was caused due to streams of corkscrew shaped tiny helical particles, which circulated through parallel threaded pores in the magnet. They entered the magnet through the South pole and came out from the North pole. This theory remained in force until the early nineteenth century. Edmond Halley (1656-1742), an English astronomer, geophysicist, meteorologist, physicist and mathematician, was a pioneer of global magnetic survey. In 1683, he proposed that the earth consisted of an inner sphere and an outer shell, both rotated at different speeds and had independent north and south poles. He opined that due to interactions between these four poles, variation in declination and dip occurred. Between 1698 and 1700, Halley sailed the Atlantic to measure variations in declination and charted them on a map. In 1800, French physicist Charles Augustin Coulomb (1736-1806) and French mathematician Simon-Denis Poisson (1781-1840) assumed distance forces resulting from fluids locked in magnetic substances.

However, during 19th century, German naturalist and explorer, Alexander von Humboldt (1769-1859), Norwegian geophysicist, Christopher Hansteen (1784-1873) and German mathematician Carl Friedrich Gauss (1777-1855) formulated relationship between data, theory and mathematical analysis in studies in terrestrial magnetism. In 1805, Humboldt reported that magnetic intensity varied across the earth's surface. To plot these variations, he encouraged the establishments of a network of magnetic observatories. In 1834, Gottingen Magnetic Union suggested recording of simultaneous magnetic observations at 50 stations, including six in Asia. Christopher Hansteen travelled to Siberia around 1830

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for geomagnetic investigation. The expedition brought fresh ideas and the evidence to geomagnetic studies. In 1830s, Gauss and Wilhelm Weber (1804-1891) did extensive magnetic measurements and launched *Magnetische Verein* (magnetic union) to establish a network of magnetic observatories worldwide. In 1838, Gauss opined that the Earth's magnetic source is at or very near its centre[2]. With such back drop, geomagnetic studies commenced in India.

The Indian Scene : From Taylor to Moos

While articles on geomagnetic studies in the 19th century Europe and America are available[3,4], only a very brief report exists on such studies in India during the 19th century[5]. From an exhaustive survey of literature on studies in magnetism in India between 1850 and 1980[6], it transpired that out of 653 research papers on geomagnetism, published up to 1980, 35 reports were on studies in geomagnetism in British India, covering three major areas – Earth's magnetic field, geomagnetic variations and magnetic exploration. These studies were carried out primarily by nine European and an Indian researcher.

The first modern astronomical observatory in India was established at Madras (now Chennai) in 1792[7], by the East India Company. Thomas Glanville Taylor (1804–1848) of Royal Greenwich Observatory, London headed Madras Observatory, during 1830-1848, as an Astronomer of the East India Company. A survey of published works on magnetic studies in India revealed[8] that Taylor was the first researcher in India to publish data on geomagnetic studies[9]. In his short paper he wrote, "Notwithstanding the value which has of late years been attached to observations of the Magnetic Dip and Intensity, I may, I believe, safely state, that the whole of British India has failed to put on record a single good set of experiments to this end". He made observations of the magnetic dip and intensity at the Madras Observatory situated in Long. 5h. 21m. 7s.8 East of Greenwich, and Lat. 13° 4'4".8N. on the 26th April 1837. His observation showed that mean magnetic dip was 6° 52' 30", quite different from 5° 15' N which was recorded at Madras by Abercrombie (unpublished result) in 1775. Taylor thus concluded that the magnetic dip was on the increase at the rate of 1'34" in a year. Taylor left Madras on 23rd July 1837 to meet John Caldecott (1801-1849), an Englishman, who later became Director of Travancore Observatory at Trivandrum (now Thiruvananthapuram). Caldecott came to India in 1821 from England and was staying in Bombay (now Mumbai). In 1831, he was appointed Commercial Agent and Master Attendant at Alleppey as an employee of the Travancore Government in Southern India. At his bungalow at Alwaye, about 13 km NE of Cochin, he built an observatory with his portable astronomical instruments. The Travancore Observatory was founded by Raja Rama Vurma (Sri Swathi Tirumal) in 1837. Caldecott started astronomical observations from the observatory in the same year. Caldecott and Taylor made joint geomagnetic surveys at Negapatam, Manaragoody, Sheally, Pondicherry, Poothocottah, Munanamelegoody, Kalenemary, Calicut, Penaney, Chetwaye, Bolghatty, Allepee and Trivandrum between 7 August and 20 November 1837[10], but the results were not published in any scientific journal. Taylor, however, was more interested in astronomical observations. While in Madras between 1831 and 1842, he measured the position of more than 11,000 stars and published his observations in 5 volumes. Primarily for this contribution, Taylor was elected a Fellow of the Royal Society of London in 1842.

John Caldecott, on the other hand, while in London in 1838, came to know about the plan of British Government to set up a worldwide network of magnetic observatories. He arranged to buy a set of magnetic instruments from Grubb of Dublin to set up a magnetic observatory at Trivandrum. Raja of Travancore, Swathi Tirumal took keen interest in introduction of European scientific ideas in his estate and provided necessary funds to set up magnetic and meteorological observatory at Trivandrum in 1841. Unfortunately results of the observations of Caldecott were never published. In 1840, John Caldecott was elected a Fellow of Royal Astronomical Society of London. With an aim to carry out magnetic survey of India, Captain H.A.D. Frasar of Survey of India visited Europe in 1841 for acquiring preliminary knowledge on magnetic surveys and also to identify necessary instruments. During 1841-1845 Simla Observatory recorded magnetic date. It, however, discontinued measurements from 1846[11].

John Allan Broun (1817-1879), a Scottish meteorologist made significant contribution in the field of geomagnetic studies when he was Director of the Trivandrum Observatory during 1852-1865. Broun had previous experience of working as Director of the magnetic observatory at Makerstoun in Scotland from 1842 to 1849. He believed that the Earth looses or gains magnetic intensity not locally, but as a whole and also found that solar activity caused magnetic disturbances. His research communications from Trivandrum Observatory described studies of mean magnetic declination, horizontal force of the Earth's magnetic field, diurnal variation of magnetic declination etc[12]. He was elected a Fellow of the Royal Society of London in 1853.

Henry Piddington (1797–1858) an English scientist, an official of East India Company and President of Marine Courts of Calcutta, while conducting magnetic studies at Saugor in Bundelkhand in 1849 noticed a very remarkable deviation of the reading of a prismatic surveying compass. He concluded that presence of a highly magnetic diorite ore in that locality was responsible for such an unexpected result. In an elaborate article, Piddington, in 1851, gave an account of studies on variation of rate of chronometers installed in ships due to terrestrial magnetism[13]. He wrote many research papers in diverse

fields, like mineralogy and meteorology, in the Journal of the Asiatic Society of Bengal.

The East India Company, on the recommendation of German naturalist and explorer Alexander von Humboldt, commissioned three German brothers Hermann Schlagintweit (1826-1882), Adolphe Schlagintweit (1829-1857) and Robert Schlagintweit (1833-1885) to carry out geomagnetic survey in India. Schlagintweit brothers were scientific explorers and great collectors of natural zoological, botanical and geological specimens[14]. They arrived in Bombay on 26th October 1854 and for the next three years travelled in various parts of the country, sometimes in company and sometimes separately. Hermann made magnetic observations at Sikkim, the Khosia Hills and Assam between April and December 1855 which included studies of magnetic dip and vertical force of Earth's magnetism. Between January and May 1856, Hermann made magnetic observations at Nurigoon in Bhutan, at Tejpur, Dibroogarh and Gowhatty in Assam, at Dacca and Khoolna in East Bengal, at Benaras, Lucknow, Agra and Meerut in Uttar Pradesh and also at Calcutta. He measured magnetic dip and declination at these places. Robert conducted magnetic surveys at Shapore, Mooltan, Shikarpore, Sehwan, Kurrachi and Bhooj between December 1856 and March 1857. Adolphe Schlagintweit carried out magnetic studies at Agra, Saugaor, Dumoh, Jubbulpore, Nagri (south of Nagpore), Rajamundry, Pondicherry, Ootacamund and Bangalore between November 1855 and April 1856. During the same period, Robert carried out magnetic and meteorological studies at Jubbulpore, Umerkuntuk Hills, Rajmeergurh Hill, Nahun and Simla. Robert and Adolphe jointly conducted magnetic survey from April to October 1855 at Benaras, Nynee Tal, Badrinath, Milum, Mana, Nelong, Ussila and Mussoorie. Together with the magnetic surveys, Schlagintweit brothers always made meticulous observation of temperature, moisture of the atmosphere, direction of wind etc. at every site[15]. After completion of their assignment, Hermann and Robert returned to Europe in early 1857. Adolphe remained to prosecute his explorations in Central Asia, but was put to death by the Amir of Kashgar in China in August 1857. Hermann and Robert published a four volume report titled 'Results of Scientific Mission to India and High Asia' between 1860 and 1866[16].

Colaba Observatory, located on the island of Colaba near Bombay, was established in 1826 by the East India Company for astronomical observations and time-keeping purposes to provide necessary information to ships using Bombay as a port. Magnetic and meteorological studies were started at the observatory in 1841. Arthur Bedford Orlebar, a Professor of Astronomy at Elphinstone College, Bombay conducted studies in geomagnetism at the observatory intermittently between 1841 and 1845[17]. From 1846, when the observatory was properly equipped, it started regular magnetic measurements. Charles Chambers was appointed as the first full-time Superintendent of Colaba Observatory in 1865. He equipped the observatory with autographic instruments for continuous recording of magnetic and meteorological observations. Between 1869 and 1893, he contributed eleven papers[18] on terrestrial magnetism. He investigated the solar variations of magnetic declination at Bombay, absolute direction and intensity of Earth's magnetic force and its secular and annual variations, secular variations of magnetic dip at Bombay during the years 1867–1893, etc. He was a Fellow of the Royal Society of London.

After the demise of Charles Chambers in 1896, Dr. Nanabhai Ardesher Framji Moos (1859-1936), a Doctor of Science of Edinburgh University, was appointed as the Director of Colaba Observatory. He was the first Indian to hold this position. He continued research in geomagnetism for nearly 24 years. In 1896, he gave an account of his predecessors in a publication titled "Fifty years of magnetic and meteorological observations at Bombay". Moos had studied the patterns of hourly variations of declination and horizontal and vertical forces on selected quiet days for the periods 1894-97, 1898-99, 1900-1901 and 1901-1905. His most important publication was on "Colaba magnetic observations : 1846-1905" in two parts, published by Government Observatory, Bombay in 1910. While the first part of the report described the magnetic observations and instruments used, the second part presented magnetic phenomenon and discussion on the observations[19]. He was a Fellow of the Royal Society of Edinburgh. In 1900, authorities of Colaba magnetic observatory came to know that electrical traction would be introduced in the city of Bombay soon, which might disturb magnetic observations. The observatory was shifted to a new location at Alibag, about 31 km south-east of Bombay. Since 1904 the Alibag Magnetic Observatory has provided uninterrupted record of geomagnetic observation.

Geomagnetic studies and surveys were of great importance in 19th and 20th Century British India and also in independent India. The origins of Earth's magnetic field, however, remains a long-standing issue and we do not have any scope to discuss on that topic in this article.

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